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Distribution of Lobster Larvae on the Scotian Shelf: 1978-1981

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ABSTRACT

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During the Scotian Shelf Ichthyoplankton Program lobster larvae were sampled with neuston nets over the entire Scotian shelf at distances greater than about 30 km from shore each year from 1978-1981. Eastern Georges Bank was also sampled in 1978. With the exception of a few samples taken east of Cape Breton in 1978, only 20 larvae were collected in about 1,000 samples from east of Halifax. Thus, there was likely little larval production within or import of larvae to this large area. The majority of larvae was found on Georges and Browns Banks during August-September, 1978. However, in all years the oldest larvae (stage IV) were also dispersed to the northeast toward Halifax. Summer winds could explain this dispersion off the Banks.

RÉSUMÉ

Watson, F.L. and R.J. Miller. 1991. Distribution of lobster larvae on the Scotian Shelf: 1978 - 1981. Can. Tech. Rep. Fish. Aquat. Sci. 1801: 24p.

Dans le cadre du programme sur l'ichtyoplancton de la plateforme néo-écossaise, on a procédé chaque année, de 1978 à 1981, à l'échantillonnage des larves de homard au moyen de filets àneuston sur l'ensemble de la plate-forme, dans un rayon supérieur à environ 30 km des côtes. On a également effectué un tel échantillonnage sur le banc Georges en 1978. A l'exception de quelques échantillons prélevés à l'est du Cap-Breton cette même année, on n'a recueilli que 20 larves dans environ 1000 échantillons provenant d'endroits situés à l'est de Halifax. Selon toute vraisemblance, la production interne ou l'importation de larves dans cette vaste zone a été minime. La majorité des larves recueillies ont été captuées sur le banc Georges et sur le banc de Brown en août et septembre 1978. Toutefois, durant toutes les années considérées, certaines des plus vieilles larves (stade IV) ont également été trouvées au nord-est, vers Halifax. Les vents d'été pourraient être à l'origine de cette dispersion loin des bancs.

INTRODUCTION

Inshore lobster fishermen in southern and western Nova Scotia have strongly objected to the existence of an offshore lobster fishery since its inception in 1971. Among their objections is the possibility that the offshore fleet catches females which would otherwise produce larvae that would in turn drift inshore to "seed" their fishing grounds. This study investigates that possibility.

The Canadian offshore lobster fishery began in 1971 when licenses were made available to vessels displaced from the swordfish fishery. The swordfish fishery was closed because of unacceptable levels of mercury. Five lobster licenses were issued initially, which increased to seven in 1973 and to eight in 1975, after which no new entrants were permitted. Offshore landings expanded from 100 t in 1971 to a high of 799 t in 1986. Beginning in 1985 each license was given an allocation of 90 t for a total allowable catch (TAC) of 720 t. The high catch in 1986 resulted from an adjustment in the start of the quota year (Wilder 1974; Pezzack and Duggan 1988). In 1988 landings for the offshore fishery was 5% of the catch in the two adjacent inshore Lobster Fishing Areas (LFA 33 and 34), extending from Digby to Halifax.

The offshore fleet is only permitted to fish at distances greater than 50 nm (91 km) from shore. The areas fished in 1988 were a 100 km long portion of the outer edge of the Scotian Shelf south of Browns Bank, the southeast edge of Georges Bank, the Northeast Channel, Georges Basin, and Crowell Basin (see Fig. 1 for place names). Browns Bank was fished until 1979 when it was closed to protect a known lobster spawning area (Pezzack and Duggan 1988).

In January 1988 the Minister for the Department of Fisheries and Oceans announced his intent to issue four additional offshore licenses and add 360 t to the TAC. The additional catch was to be taken from the Scotian Shelf east of the established offshore fishing areas (Pezzack and Duggan 1988). However, after receiving strong objections from inshore lobster fishermen he suspended these licenses the following April, pending further studies on the impact of the expanded fishery on inshore catches. The objections raised were the same as those voiced by inshore fishermen when the fishery was initiated in 1971. As stated by Wilder (1974) "They contended that heavy offshore landings would depress lobster prices, that offshore stocks contributed to the inshore fishery from inshore movement of lobsters, either in the adult or larval stages, and that a year-round offshore fishery would be impossible to police with the result that inshore grounds would be fished illegally." With only about 2% of Canadian landings coming from the offshore, impact on prices must be negligible. The absence of violations detected by fishery officers and scarcity of accusations by inshore fishermen suggest the fears of offshore vessels fishing inshore grounds were unfounded (Wilder 1974; Regulatory and Legal Affairs Branch, D.F.O., Halifax, pers. comm). The contribution of offshore stocks to the inshore fishery is still unresolved, especially in southwest Nova Scotia, although the issue has not lacked attention.

Several authors have considered the inshore-offshore question using tagging, larval distributions, and size frequencies. Wilder (1974) concluded that little mixing occurred between adult lobsters inshore and offshore based on results of tagging and the observation that lobsters offshore were much bigger. Stasko (1978) offered the hypothesis that some legal sized lobsters migrate from inshore southwest Nova Scotia to offshore grounds on or near Browns Bank. There they release larvae which drift onshore to supplement scarce local production. This hypothesis was based on the distribution of ovigerous females, larval distribution, surface currents, and tagging studies. Using the same data on larvae and currents, Harding et al. (1983) hypothesized that a large fraction of larvae recruiting to inshore southwest Nova Scotia could originate from the north side of Georges Bank. With more data on surface currents, Harding and Trites (1988) concluded that most larvae released on Browns Bank would drift north well into the Gulf of Maine before settling to the bottom. Based on recent data describing the distribution of ovigerous females, Campbell and Pezzack (1986) concluded that larval production was substantial both on offshore banks and in the coastal zone. Tagging results from southwest Nova Scotia suggest that some lobsters >95 mm

carapace length (CL) move from inshore to offshore, but practically none do the reverse (Campbell et al. 1984; Campbell and Stasko 1985; Pezzack 1987a; Campbell 1989a), as would be the case in an inshore spawning migration. Unfortunately this result is clouded by poor cooperation from inshore fishermen in returning tags. It is unlikely that lobsters <95 mm CL move between the offshore and inshore because extensive tagging studies have shown that they move no more than a few kilometers in any direction (Campbell 1989a; Miller et al. 1989).

Interchange between adult lobsters inshore and offshore is unlikely to occur on the Scotian Shelf east of the present offshore fishing grounds. Lobsters are rarely caught between inshore grounds and offshore banks, and year-round cold bottom temperatures between inshore and offshore grounds should discourage migration (Pezzack 1987b).

During 1978-1982 the Scotian Shelf Ichthyoplankton Program (SSIP) investigated the spatial and temporal distribution of fish eggs and larvae from Georges Bank to eastern Cape Breton (O'Boyle et al. 1984). Lobster larvae were also collected and removed during sample sorting. This report uses larval distributions from the SSIP surveys, as well as from previous surveys by Stasko (1977) and Stasko and Gordon (1983), and considers the effect of wind on larvae transport to investigate the possibility that larvae released offshore seed inshore grounds.

METHODS

Only SSIP samples taken by neuston nets were considered here. From an approximately equal number of neuston and oblique tows four times as many neuston samples contained larvae. The standard neuston net had a 100 by 34 cm mouth opening, 1179 µ mesh, and fished the top 15 cm (Roff et al. 1984). Each 30 min tow swept a surface area of 3,600 m^2 and filtered 540 m^3. A Sameoto box neuston net was substituted during two of the 12 cruises included in this report. It had a 0.5 m^2 opening, 405 µ mesh, and sampled about 1,800 m^2 of surface and 720 m^3 volume, assuming that the speed and duration of tow were the same as for the other neuston samples.

Two hundred and sixteen vials with larvae were obtained from the Atlantic Reference Center (ARC), St. Andrews, New Brunswick, where they had been stored in formalin since the larvae were removed from the original collections. Numbers on these vials were cross referenced to the SSIP data base to obtain station location, date, cruise number, gear type, and surface temperature. Of the 216 samples 36 were excluded because no corresponding vial numbers were found in the data base, and a further 49 were excluded for a variety of reasons listed in Table 1. Stations which were sampled by neuston net, but had no corresponding vial containing lobster larvae were assumed to have yielded a zero catch. The SSIP data base could not be used to determine if any vials were missing because lobster larvae were not recorded. We were unable to locate any former sorters to interview, but L. VanGuelpin (ARC, pers. comm.) believes that all sorters were trained to identify and remove lobster larvae. Also, L.P. Fanning (D.F.O., Bedford Inst. Oceanography, Dartmouth, N.S., pers. comm.) sorted the 1978 collections for crab larvae and noticed that lobster larvae had been removed. We separated larvae into molt stages I, II, III, and IV.

Spatial distributions of lobster larvae are presented on a series of maps according to molt stage, season, and year. Stage IV larvae were separated from stages I, II, and III because this is the stage when the lobster leaves the plankton for a benthic life style. Data from 1978 were separated into early (May 15-July 15) and late (August 4-October 12) seasons because larval distributions were radically different. The years 1979-82 were combined because only a few larvae were collected in any year and collections were nearly all taken during August-September (Table 2).

Progressive wind vectors were obtained for the larval period because wind powered surface drift was a possible mechanism for larval transport. Wind speed and direction data recorded at Yarmouth and Cape Sable Island (data from Environment Canada, Bedford, N.S.) were plotted as progressive vectors for

Julian days 203-243 and 233-263. The straight line distance and compass direction between start and end points were measured for each locality for each year from 1973-1982.

RESULTS

LARVAL DISTRIBUTION

1978, May-July: Stations from Georges Bank to eastern Cape Breton were sampled twice. All 97 larvae collected came from five stations near the coast in Sydney Bight (Fig. 2), and all but one larva were taken on July 8-9.

1978, August-September: Stations from Georges Bank to eastern Cape Breton were sampled one to three times each. Fifty-nine of the 66 stage 1, II, and III larvae were taken on or near Georges and Browns Banks. The remainder were scattered over seven other station locations (Fig. 3). Most of the 1,006 stage IV's were also taken on the two banks, but some were scattered a short distance to the northwest towards the Bay of Fundy and a greater distance to the northeast along the Scotian shelf (Fig. 4). Highest densities of IV's were obtained between August 6-16; 348 were collected at a single station on Browns, 180 at two stations on Georges, and 66 at one station between the banks.

1979-81, August-October: Georges Bank was not sampled during 1979-81, but most of the remaining stations were sampled 5-7 times each from early August through early October. Appropriate samples were not obtained during other months (Table 1). Larvae of stages I, II, and III, 17 in total, were collected mostly over Browns Bank (Fig. 5), whereas most of the stage IV's were found to the northeast of Browns (Fig. 6). We presume that the low number of larvae collected in 1979-81 relative to 1978 represent true abundance, but the possibility of less complete sorting in the later years cannot be ruled out.

WIND TRANSPORT

Wind powered surface drift was considered to be a possible mechanism for transporting larvae away from Browns Bank and towards shore. Possible transport was determined for larvae hatched in late July and late August ~~previous~~ because these were the earliest and latest dates that a study (Stasko and Gordon 1983) found stage I larvae on Browns Bank. Using the surface temperatures from Browns during late July-early August and for the shelf east of Browns for the remainder of August, using temperature dependent larval development times from MacKenzie (1988), and assuming that larvae settle to the bottom midway through stage IV (Scarratt 1973), larvae hatched in late July (e.g., July 22, Julian day 203) would settle in about 40 d. Larvae hatched near the end of August (e.g., Julian day 233) would settle in about 30d because warmer temperatures speed development.

Ten years data for the length and direction of progressive wind vectors agreed reasonably well between the two sites (Table 3).

Now that the starting and ending dates of larval life, and the wind speed and direction for those dates are known, the next task is to convert the wind vectors to larval drift vectors. Classical Ekman transport predicts that water will be transported 45° to the right of the wind at the surface and 90° to the right when averaged throughout the depth of the wind's influence on the water column (Gross 1982). However, density change with depth, a shallow sea bottom that interferes with wave motion, or changes in wind direction can considerably reduce the angle of deflection of water transport. F. Nanson (quoted in Gross 1982) found that sea ice drifted 20-40° to the right of the wind. Garratt et al. (1985) observed that icebergs, with a draft that probably exceeded the mixed layer, drifted nearly downwind. Petrie et al. (1987) used a coastal upwelling model applied to the south coast of Nova Scotia to predict that drift downwind was five times the velocity of drift at right angles to the wind. This results in drift that is deflected about 10°. Gross (1982) states that surface water is transported at about 2% of the wind speed. Garratt et al. (1985) measured iceberg drift at 1.8±0.7% of wind

speed, and Lawrence and Trites (1983) considered 3% appropriate for modeling drift of surface oil slicks. Because drift speed decreases with depth (Gross 1982), the depth of lobster larvae in the water column must be considered.

Lobster larvae probably spend about 30% of their pelagic life in the surface meter, and the remainder between 5 and 20 m. This is based on the development times of each stage (MacKenzie 1988) and their vertical distribution. Stages I-III on Browns Bank were distributed throughout the top 20 m, whereas stage IV's were predominantly within the top meter (Harding et al. 1987).

Forty vectors were plotted for each of early and late larval release dates, starting from points on western Browns Bank and Baccaro Bank (also called eastern Browns Bank) (Fig. 7). The vectors were deflected both 0° and 40° to the right of the wind to represent the extremes of larval drift likely to occur. Because larvae spend most of their time beneath the surface meter, speed of drift was reduced to 1.5% of wind speed. Early season larval releases would have been carried further and more to the north than late season releases. The endpoints for the 0° deflection represents the observed distribution of stage IV's (Figs. 4 and 6) better than the endpoints for the 40° deflection.

DISCUSSION

SYDNEY BIGHT

Stage I larvae sampled during July 1978 probably hatched near the location of capture. The duration of the first larval stage at the 13°C surface temperature is 7-8 d (Templeman 1936; MacKenzie 1988). Currents for this area and season flow from the Gulf of St. Lawrence at about 11 km/d (El-Sahb 1977). Thus, even at the end of this first developmental stage, larvae would have drifted no further than 88 km. Because the three stations yielding 90 of the 97 larvae were located nearshore the larval source was also likely nearshore.

SCOTIAN SHELF EAST OF HALIFAX

The scarcity of larvae indicate that few were released there and that few drifted there from other areas, such as nearshore. Excluding the few stations in Sydney Bight mentioned above, only 20 larvae of all developmental stages were collected from approximately 1,000 samples taken east of Halifax during 1978-81. In an earlier study Stasko (1977) made one neuston tow at each of 76 stations distributed over the Scotian Shelf during August 12-24. Only three larvae were taken at 41 stations east of Halifax. In the same report Stasko summarized studies by McKenzie and Wilder and Graham which included results from 217 neuston tows on the Scotian Shelf, most east of Halifax. No larvae were captured, although most sampling was in July and could have been before the time of peak abundance.

SCOTIAN SHELF WEST OF HALIFAX AND GEORGES BANK

The more frequent collection dates of Stasko and Gordon (1983) indicate that the SSIP collections were taken at the right season to obtain early and late stages. During 1977 and 1978, Stasko and Gordon sampled from south of Browns Bank at the shelf edge into shore along southwest Nova Scotia (Fig. 8). The portion >10 km from shore overlaps the area sampled by SSIP and is reviewed here. The area was sampled on six cruises between early July and early September both years using a neuston net and subsurface meter nets sampling as deep as 2 m. Collections taken from 5-15 July and covering 190,000 m^2 of ocean surface obtained only two larvae. Stage I's were most abundant during August 8-11, 1977 and August 14-18, 1978. Stage IV's were most abundant on August 22-25, 1977 and August 21-25, 1978. The highest abundances of both stages I and IV were obtained on two SSIP cruises during August 6-25, 1978. Thus, SSIP cruises were probably well timed.

The most abundant larval stage in SSIP collections was fourth, and all were caught between August 6 and October 8. This dominance may be due to the

longer duration of stage IV and stage differences in depth distribution. Stage IV larvae are in the water column about twice as long as stage I larvae (Mackenzie 1988). Harding et. al (1987) used a large opening and closing net to obtain discrete depth samples during late August over Browns Bank. Stage IV's were nearly all found in the top meter both day and night, whereas stage I's were almost absent from the surface meter during daytime and only one-quarter at the surface at night. They found that stage I's undergo a diurnal vertical migration on the order of 20 m. Although relatively rare, stages II and III were distributed throughout the top 20 m day and night. Stasko (1977), Stasko and Gordon (1983), and SSIP (excluding Sydney Bight) obtained the following number of larvae in neuston tows. Stage IV's dominated all series.

	Stage					
Year	I	II	III	IV	Total	Source
1976	10	9	19	72	110	Stasko (1977)
1977	206	35	12	268	521	Stasko and
1978	12	12	12	329	365	Gordon (1983)
1978	24	13	29	1006	1072	SSIP
1979-81	3	2	12	24	41	SSIP

LARVAL TRANSPORT

Early stage larvae were likely hatched near where they were collected on Browns Bank and Georges Bank. Stasko and Gordon (1983) found stage I's on Browns and to the northwest of Browns during both 1977 and 1978 (Fig. 8). In SSIP collections stage I's were caught on or near Browns and eastern Georges. Females with ripe eggs were abundant on Browns and eastern Georges during June and July (Campbell and Pezzack 1986), before the August appearance of early stage larvae. August surface temperatures on Browns ranged from 8-18°C and averaged 14°C. Mean August surface temperatures on Georges were about 17°C. Development times for stage I larvae are 6, and 4 d at 14.2, and 17.9°C respectively (MacKenzie 1988). Since the surface water on the western end of Browns has an average retention time of 14 d (Smith 1989), stage I's captured there are likely to have been hatched there. Summer surface circulation on eastern Georges is a clockwise gyre with a velocity of up to 18 km/d (Loder and Wright 1985). Therefore, larvae released on eastern Georges could be transported 10's of kilometers to the southwest.

Stage IV's were more widely dispersed than earlier stages, as also observed by Hudon et al. (1986) in the Gulf of St. Lawrence. Summer current direction might be invoked to explain the distribution of stage IV's to the north of Browns (Figs. 4 and 8). Drogues released on the western portion were retained in the gyre or drifted toward Yarmouth (Smith 1989). Drift cards and bottles released during the 1977 larval survey off southwest Nova Scotia (Stasko and Gordon 1983) were analyzed by Harding and Trites (1988). These showed transport north toward the Bay of Fundy, and a minor component north toward Cape Sable.

Evidence for larval transport from Browns northeast along the Scotian Shelf, as suggested by the distribution of stage IV's in SSIP collections (Figs. 4 and 6), is more equivocal. The Nova Scotia current flows southeast, parallel to shore (Sutcliffe et al. 1976), opposite to the direction implied by distribution of stage IV's. However, during summer the flow is weakest, possibly even stopping in August (Drinkwater et al. 1979; Smith 1983). R.W. Trites (Bedford Institute Oceanography, unpub. manuscript) summarized archived data for drift bottles (Anon. 1958) released on lines extending from Cape Sable Island over eastern Browns Bank. These included releases in July of 1922 and 1923, and July, August, September, and October of 1926. These data were also referred to in Harding and Trites (1988). Recoveries from all releases indicated transport north toward Cape Sable Island and Yarmouth, but some recoveries were also made to the northeast. The most easterly point of recovery was Lunenburg, 60 km southwest of Halifax.

Lawrence and Trites (1983) combined residual currents and wind vectors based on Sable Island wind data to predict drift of surface oil slicks from fixed points. They assumed that the slick was driven directly downwind at 3% of the wind speed. Their calculations most pertinent to this study is drift from a point on the western edge of Browns Bank starting on June 1 and lasting for 40 days. The end points using each of 23 years (1956-78) of wind data were on the southern side of the Bay of Fundy and on the Scotian Shelf as far as 180 km northeast of the starting point.

In the analysis of wind drift used in this report (Fig. 7) residual currents were not included, drift speed was taken to be 1.5% of wind speed and the direction of drift was deflected both 0° and 40° to the right of the wind. Predicted drift from Browns approximated the distribution of stage IV larvae in SSIP collections when the drift was taken to be directly down wind, but not when drift was deflected 40° to the right of the wind.

SUMMARY

What can larval distributions tell us about offshore spawning "seeding" inshore grounds? Because lobster larvae were rare east of Halifax (SSIP collections and Stasko 1977) we conclude that any contribution from this large area of shelf would be negligible. Distribution of berried females indicates that larval production can be high both on Browns and Georges Banks and inshore southwest Nova Scotia (Campbell and Pezzack 1986). Thus, drift may not be necessary to sustain the inshore population. Stasko and Gordon (1983) concluded that their larval sampling neither confirmed nor contradicted the hypothesis that larvae drifted from Browns Bank to inshore. Surface current measurements (Smith 1989; Harding and Trites 1988; R.W. Trites, BIO, pers. comm.) show a gyre on Browns, a current northwest towards the Bay of Fundy, and possibly components north and northeast (Harding and Trites 1988; Trites, pers. comm.). Whether this current would bring lobster larvae into shore in southwest Nova Scotia was not determined. SSIP collections showed stage IV's distributed to the northwest and especially to the northeast of Browns in diminishing densities, suggesting that Browns was the source. Residual currents could cause the northwest displacement. Displacement to the northeast by wind induced transport is also possible. We regret to conclude that the large amount of data accumulated does not give us a confident answer as to whether larvae from offshore banks seed inshore grounds in southwest Nova Scotia and east to Halifax.

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Table 1. Lobster larvae samples collected as part of the SSIP and obtained from ARC that were included and excluded from this report.

Cruise	Date	Number of samples (vials) Included	Excluded
CC01	Feb. 1977	0	1[ac]
CL01	Aug. 8-Sept. 2, 1977	0	18[a]
CC02	May 15-July 15, 1978	7	0
VY01	Aug. 6-Aug. 25, 1978	16	0
H005	Aug. 9-Aug. 16, 1978	33	1[a]
H006	Aug. 20-Sept. 1, 1978	14	0
VY02	Aug. 29-Sept. 15, 1978	16	0
VN01	Aug. 4-Aug. 19, 1979	8	0
VN02	Aug. 24-Sept. 10, 1979	13	1
HO36	June 2-June 26, 1980	0	1[a]
BR02	July 2-Aug. 5, 1980	0	7[e],2[e]
LE01	Aug. 15-Aug. 31, 1980	1	9[e]
AR01	Aug. 24-Aug. 31, 1980	0	2[b]
AR02	Sept. 2-Sept. 29, 1980	0	1[bc]
LE02	Sept. 4-Sept. 22, 1980	3	1[a]
HO45	Nov. 11-Dec. 14, 1980	0	2[ac]
EK01	Aug. 26-Sept. 12, 1981	3	1[a]
EK02	Sept. 16-Oct. 9, 1981	2	2[a]
Totals		125	49

[a]Inappropriate gear type (oblique bongo, oblique Isaac-Kidd, or subsurface meter net).

[b]Patch study using different sampling grid.

[c]Empty sample vial.

[e]Months when lobster larvae not present.

[f]Incomplete data set; listed as zero catch.

Table 2. Summary of lobster larval data collected as part of SSIP from 1978 to 1981.

Year	Month	Cruise	Gear code[a]	Number of larvae/stage I	II	III	IV	Total larvae	No. stations sampled
1978	05-07	CC02	96	88	7	2	0	97	395
1978	08	H005	96	9	5	24	741[b]	779	53
	08	VY01	96	12	4	2	117	135	147
	08-09	H006	96	3	1	0	55	59	95
	08-09	VY02	96	0	3	3	93	99	149
1979	08	VN01	99	1	2	5	3	11	126
	08-09	VN02	99	2	0	6	10	18	125
1980	08	LE01	96	0	0	0	1	1	130
	09	LE02	96	0	0	1	3	4	256
1981	08	EK01	96	0	0	0	3	3	79
	09-10	EK02	96	0	0	0	4	4	99
				115	22	43	1030	1210	1654

[a]Gear code 96 - Neuston Net

99 - Sameoto Box Neuston Net

[b]528 larvae included in 3 tows.

Table 3. Length (km) and direction (in parenthesis) of wind vectors at two recording stations for Julian days 204 to 244 and 236 to 264, for each of 10 years.

	Julian day			
	204-244		234-264	
Year	Yarmouth	Sable I.	Yarmouth	Sable I.
1973	6500 (36°)	6300 (28°)	4500 (73°)	6000 (63°)
1974	4700 (61°)	3900 (34°)	2800 (42°)	3700 (17°)
1975	4200 (74°)	2800 (55°)	3800 (85°)	2200 (60°)
1976	6800 (51°)	5100 (10°)	4800 (72°)	5000 (50°)
1977	7300 (55°)	10,400 (37°)	4000 (81°)	5300 (70°)
1978	4300 (56°)	3900 (78°)	4000 (99°)	5000 (104°)
1979	6600 (42°)	11,000 (36°)	6500 (57°)	7200 (52°)
1980	4700 (63°)	6900 (43°)	4300 (75°)	3700 (55°)
1981	4600 (56°)	2200 (21°)	700 (120°)	1500 (185°)
1982	8200 (53°)	7700 (23°)	5200 (61°)	5800 (42°)
Mean	5800 (55°)	6200 (37°)	4100 (77°)	4000 (70°)
r (distance)	0.71 (P<0.05)		0.85 (P<0.01)	
r (direction)	0.39 (P>0.05)		0.93 (P<0.01)	

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Fig. 1. Location of place names referred to in the text.

Fig. 2. The distribution of stages I, II, and III larvae combined during May-July, 1978. Number of larvae (above) and number of times a station was sampled (below) are shown next to each station location.

Fig. 3. The distribution of stages I, II, and III larvae combined during August-September, 1978. Data presentation as in Figure 2.

Fig. 4. The distribution of stage IV larvae during August-September, 1978. Data presentation as in Figure 2.

Fig. 5. The distribution of stages I, II, and III larvae combined during August-October, 1979-81. Data presentation as in Figure 2.

Fig. 6. The distribution of stage IV larvae during August-October, 1979-81. Data presentation as in Figure 2.

Fig. 7. End points of progressive wind vectors deflected 0° (O) and 40° (X) to the right of the wind direction, one point for each of 10 years for each of two recording stations. A, starting from western Browns Bank on July 23; B, starting from Baccaro Bank on July 23; C, starting from western Browns on August 22; D, starting from Baccaro on August 22.

Fig. 8. From Stasko and Gordon (1983) the distribution of stage I and stage IV larvae in southwest Nova Scotia. Data presentation as in Figure 2.

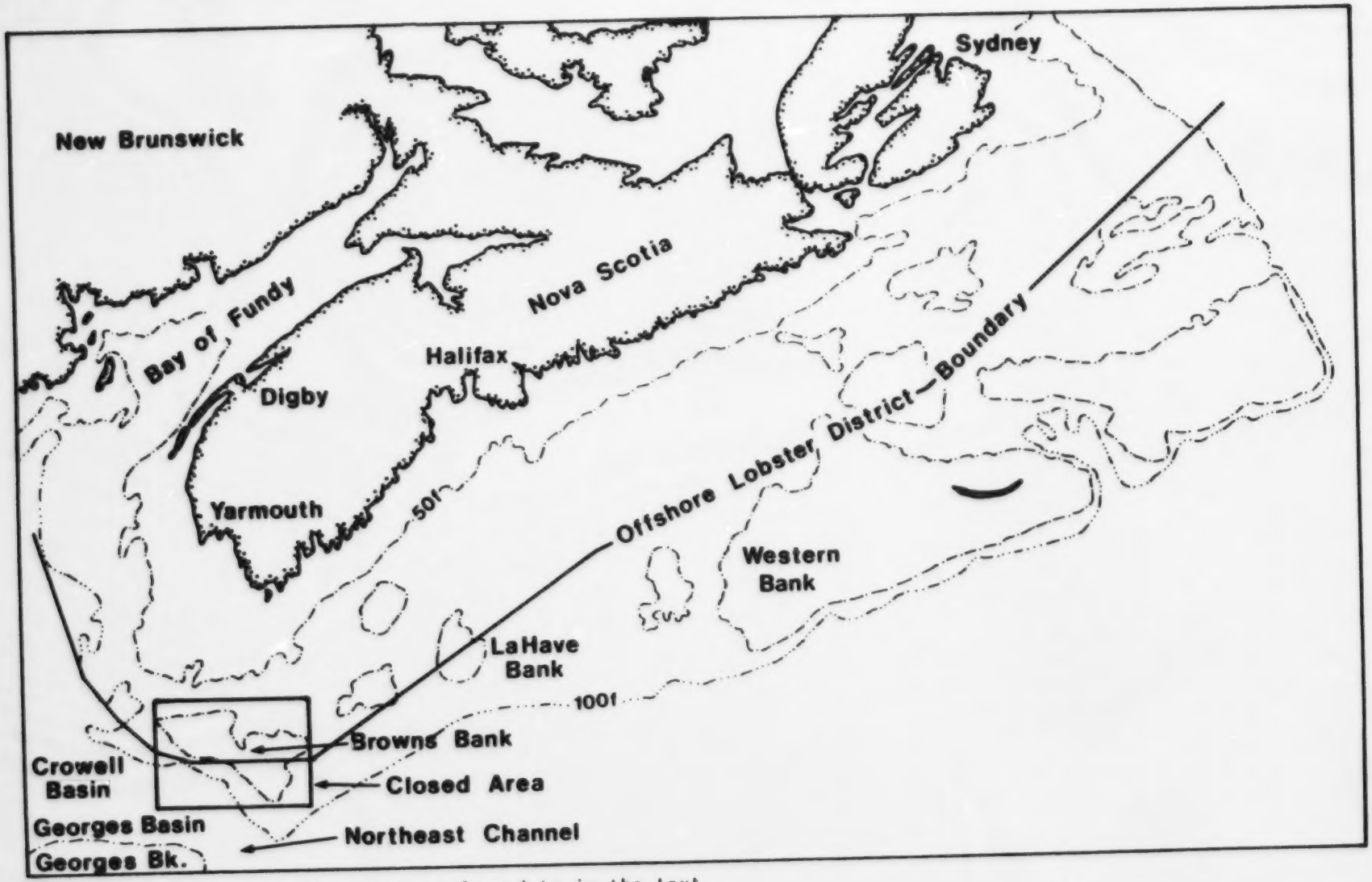


Figure 1. Location of place names referred to in the text.

Figure 2.

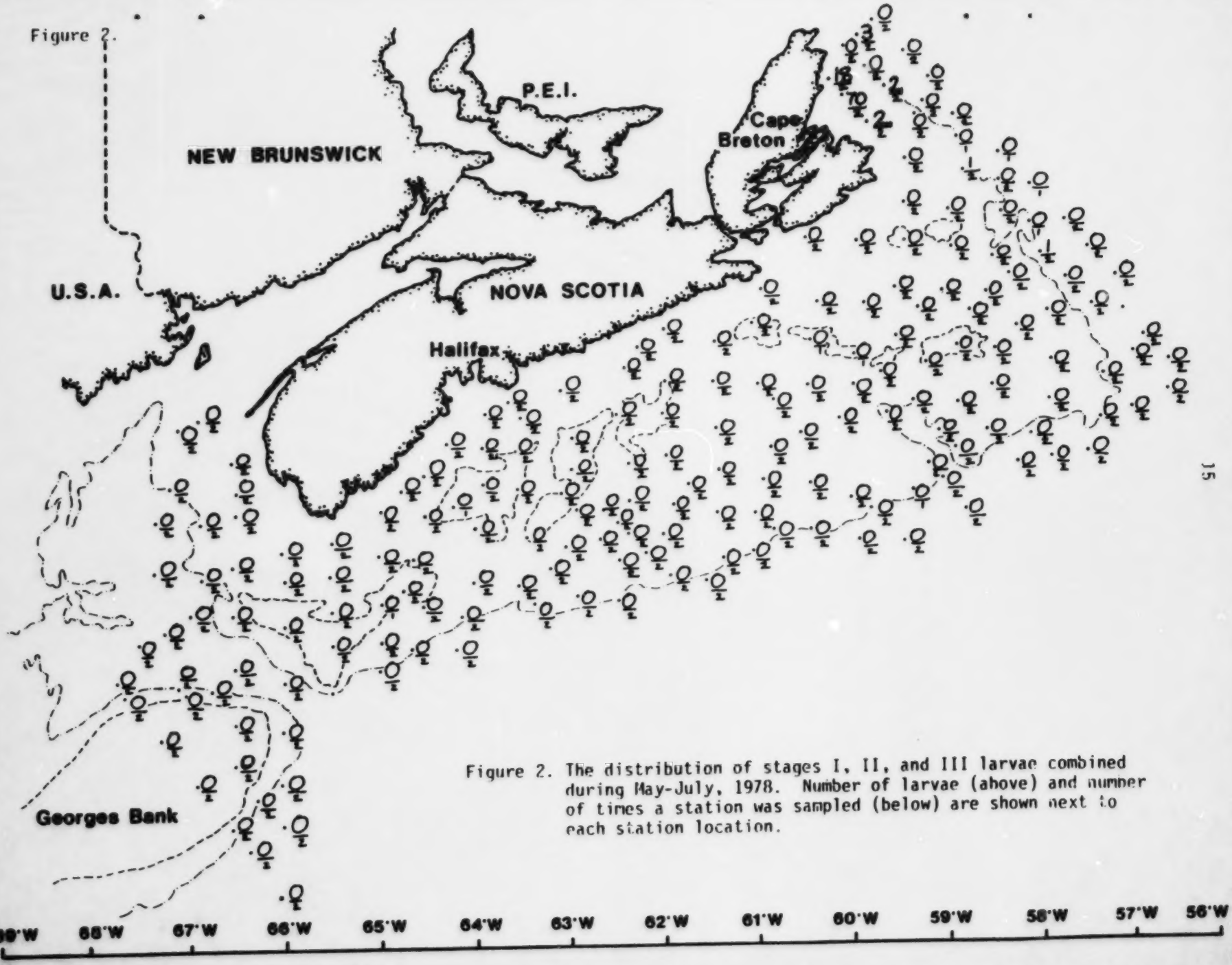


Figure 2. The distribution of stages I, II, and III larvae combined during May-July, 1978. Number of larvae (above) and number of times a station was sampled (below) are shown next to each station location.

Figure 3.

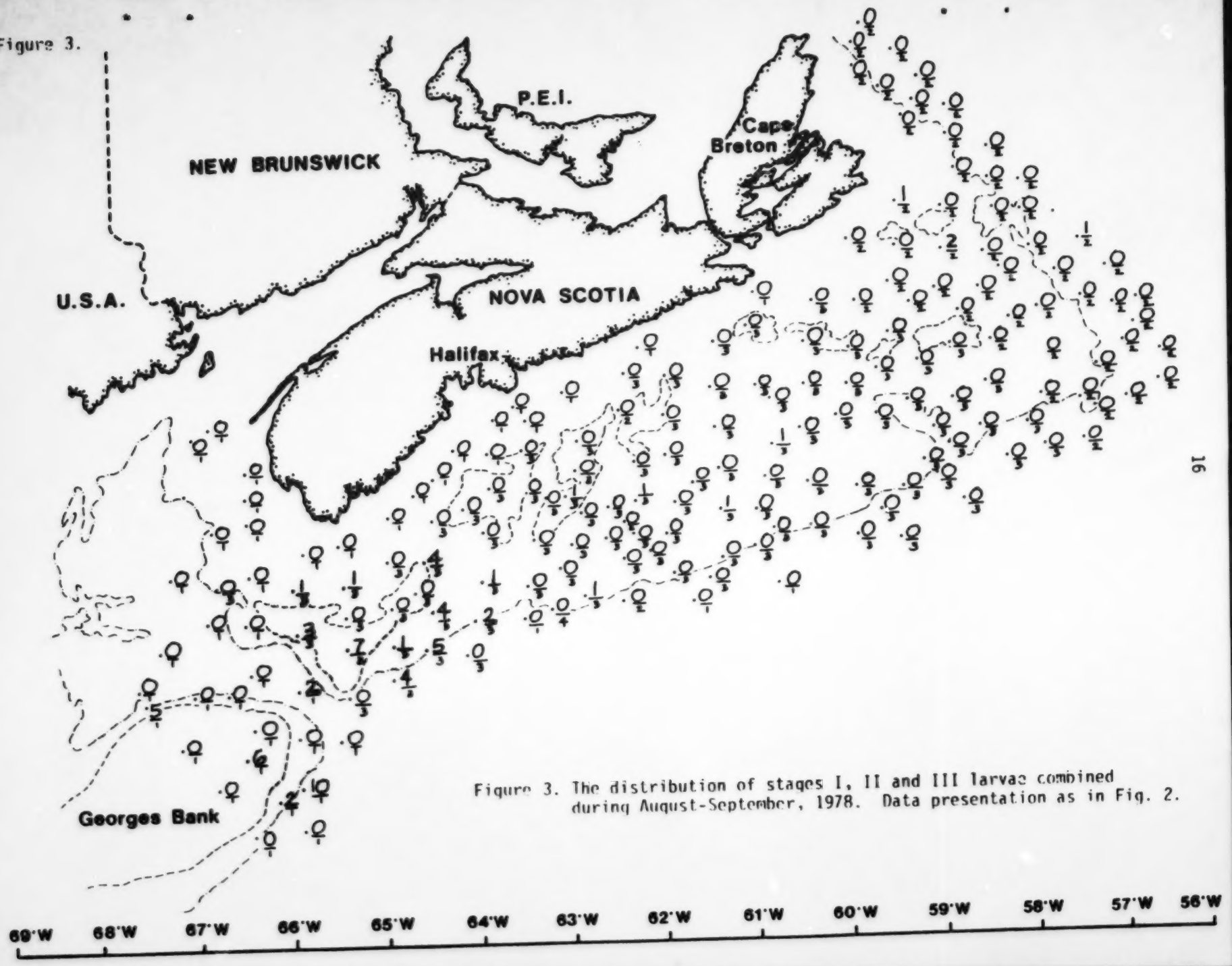


Figure 3. The distribution of stages I, II and III larvae combined during August-September, 1978. Data presentation as in Fig. 2.

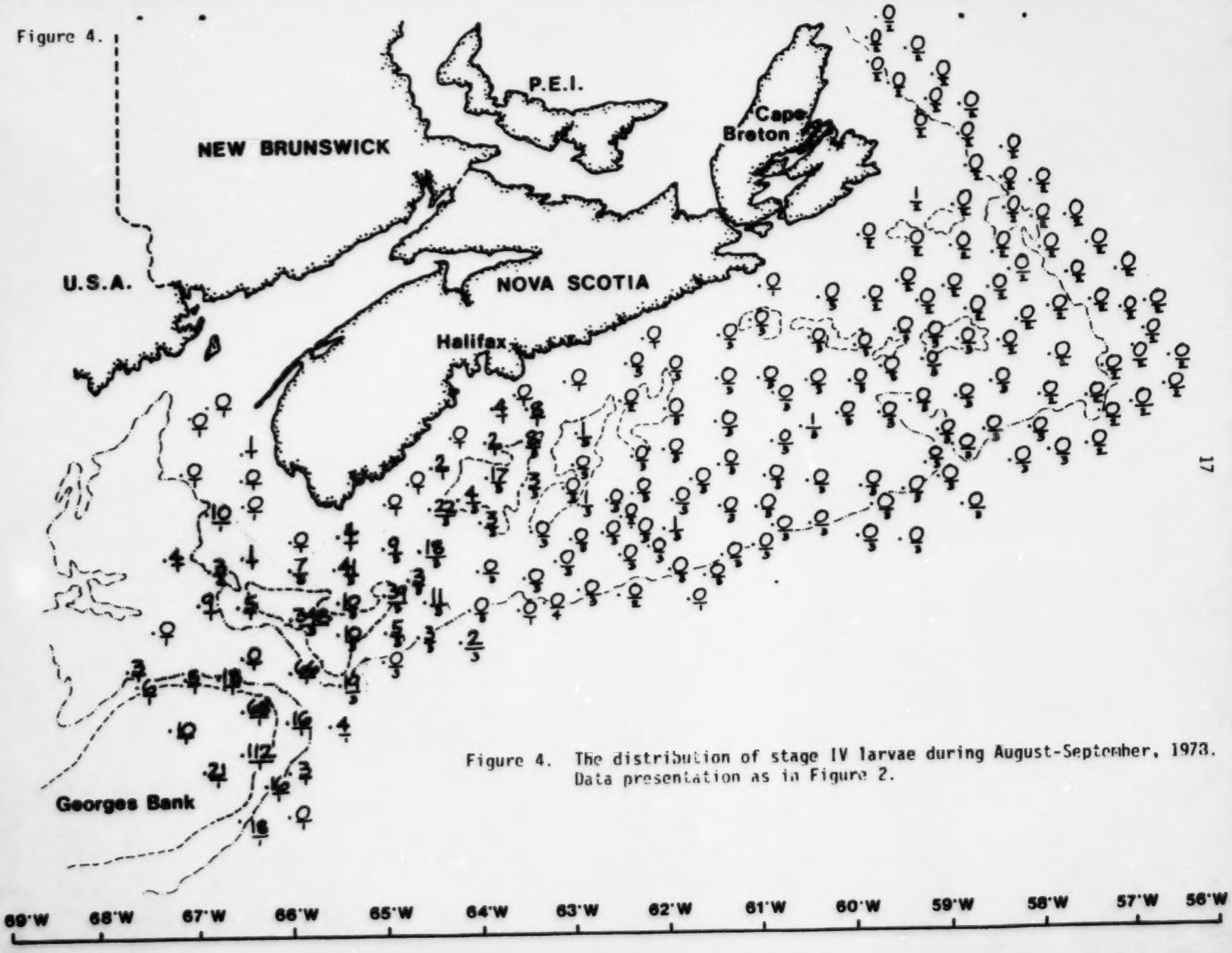


Figure 4. The distribution of stage IV larvae during August-September, 1973. Data presentation as in Figure 2.

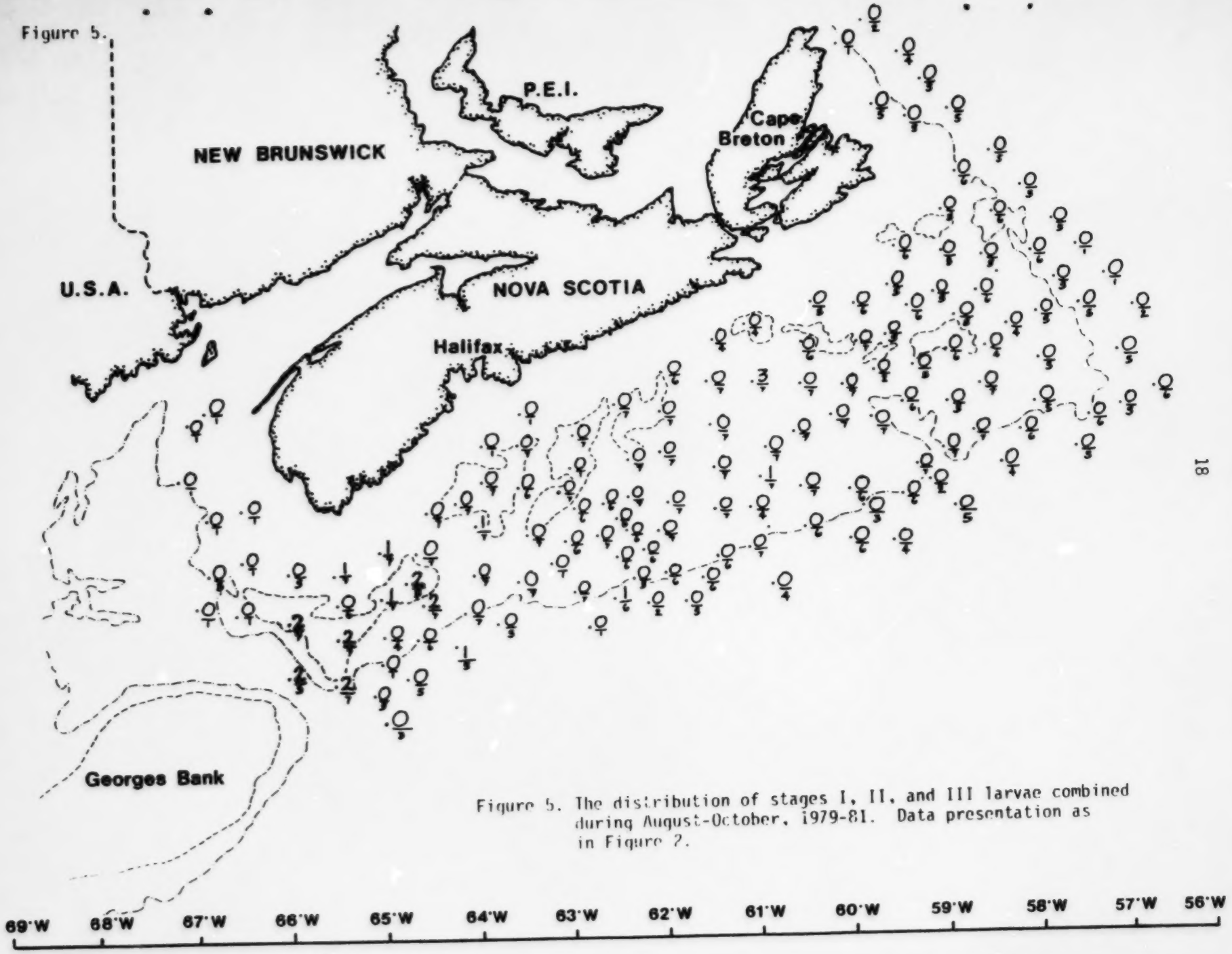
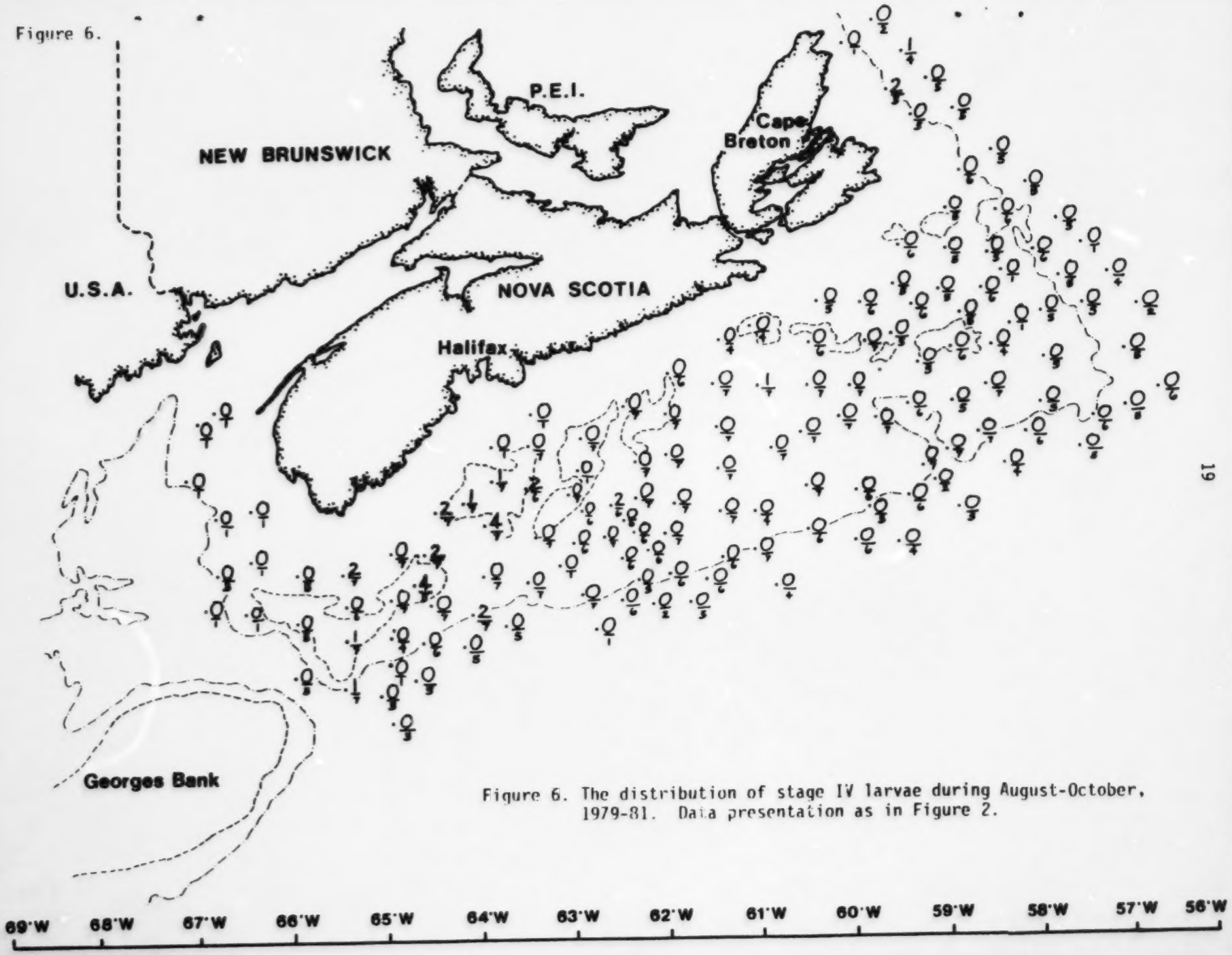


Figure 5. The distribution of stages I, II, and III larvae combined during August-October, 1979-81. Data presentation as in Figure 2.

Figure 6.



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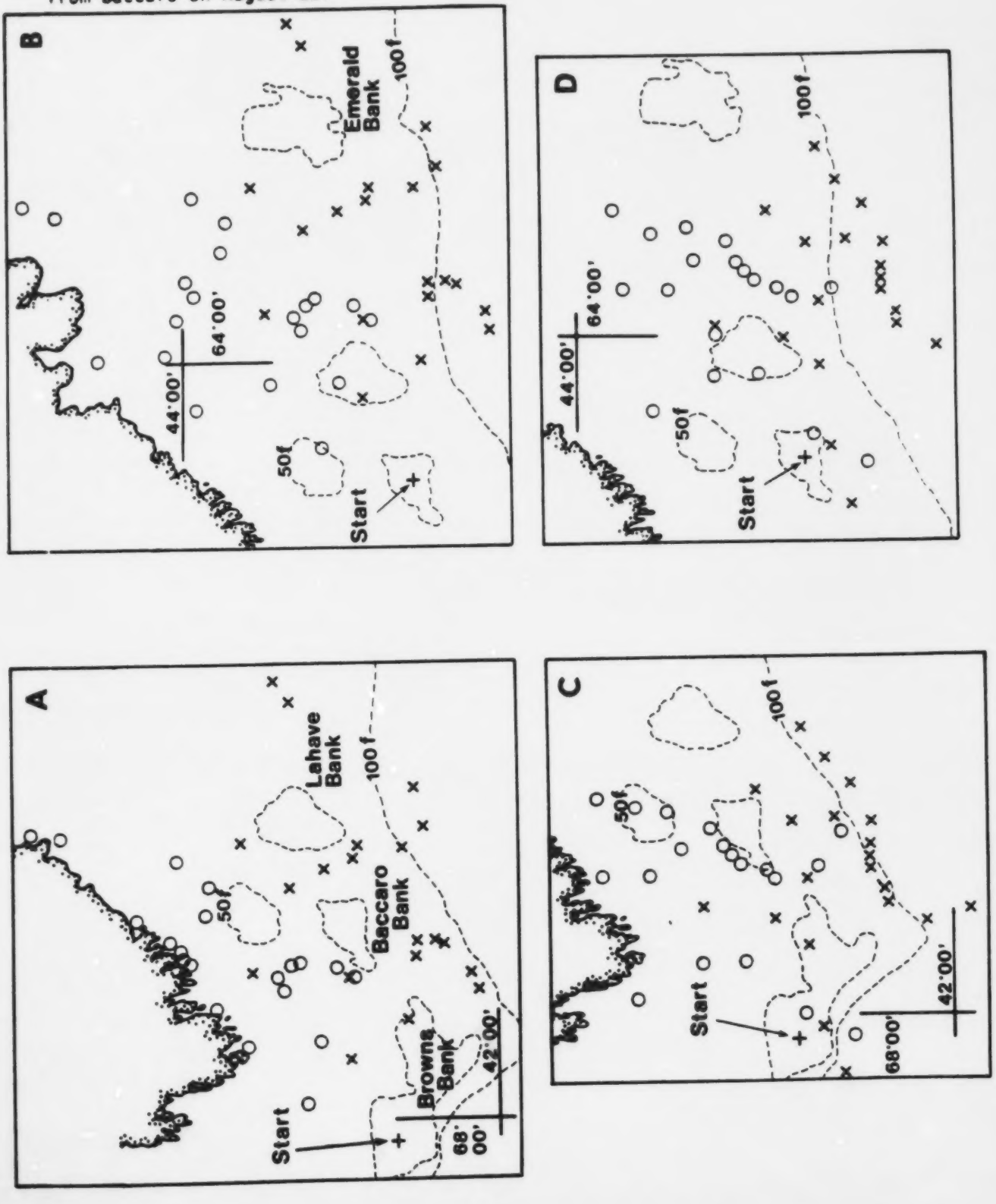
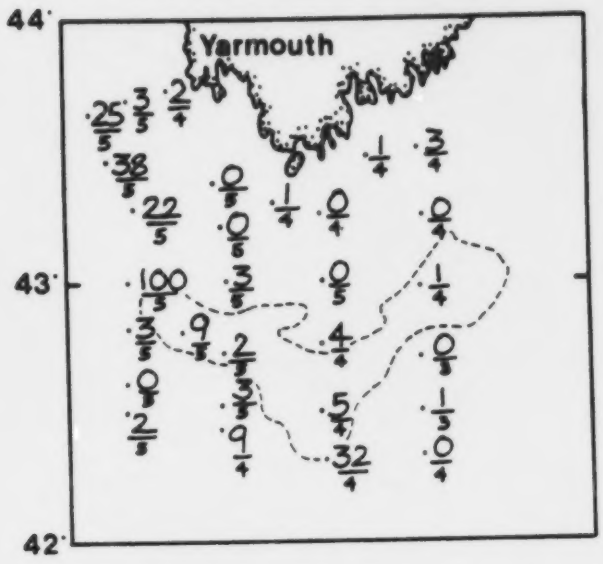
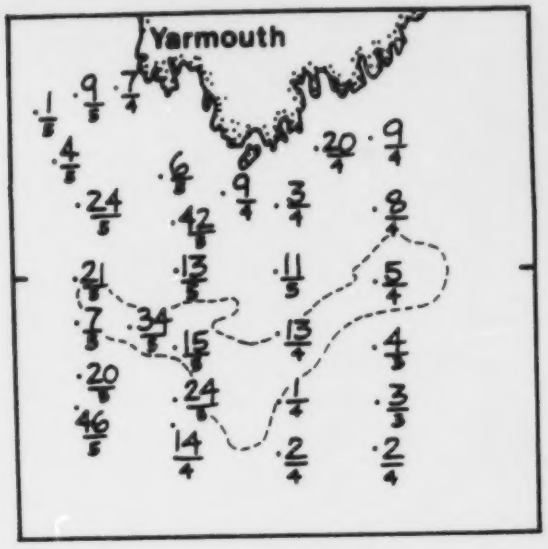


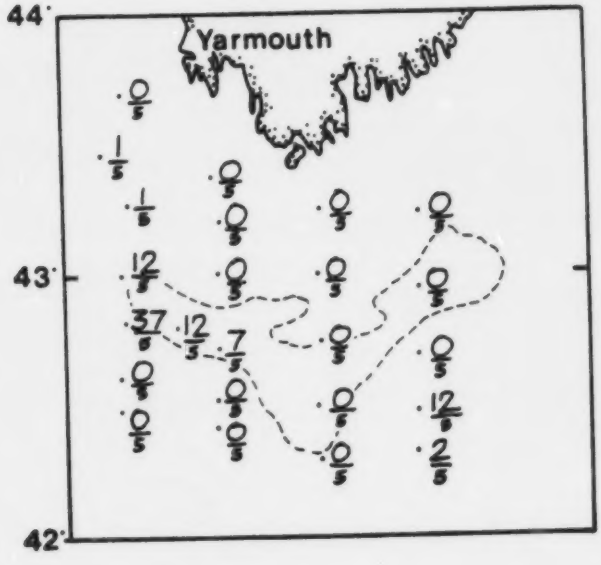
A. Stage I, July 19 - Sept 16, 1977



B. Stage IV, July 19 - Sept 16, 1977



C. Stage I, July 24 - Aug 24, 1978



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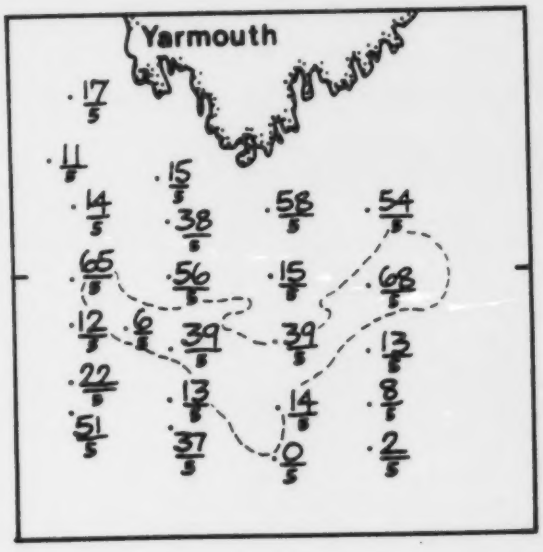

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